LED Lighting Control Using the MC9S08AW60

Designer Reference Manual

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Designer Reference Manual

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The following revision history table summarizes changes contained in this document. For your convenience, the page number designators have been linked to the appropriate location.

Revision History

Date	Revision Level	Description	Page Number(s)
03/2006	0	Initial release	N/A
07/2007	1	Overall edits for grammar, spelling, structure, and style.	N/A

Table of Contents

Chapter 1
Introduction

1.1 Introduction

This manual describes a reference design of a multi-color LED lighting control solution by using the MC9S08AW60 Microcontroller.

Using a microcontroller (MCU) to control the red/green/blue (RGB) color LEDs increases system flexibility and functionality for the next generation of lighting applications, architectural/entertainment lighting or LCD backlighting, that require a smart and adaptive control methodology to ensure optimized color space rendering for various display contents, excellent color contrast for realistic display scene and a consistent color setting in manufacturing. In many cases, these new applications are controlled by a central control unit that requires a connectivity interface that can be implemented at a low cost using MCU-based lighting controller.

A compact light-box with more than a million display colors is implemented to demonstrate the advantages of using MCU to control RGB color LEDs with different luminosity settings. The average current through each color LED is controlled by an individual PWM signal generated from MCU and the LED luminosity is almost in linear relationship with the pulse width of the driving PWM signal. The final display color is determined on the mix of light emitted by RGB LEDs, so one of the simple methods to set the light source in different color is changing the RGB PWM duty cycles equal to the corresponding mixing ratio required for a particular color. In addition, a serial control protocol with user interface is also developed as a communication link to control and monitor system parameters through a personal computer.

All hardware schematic diagrams and firmware source codes are available as reference materials.

1.2 Features

- Apply for architectural/entertainment lighting or LCD backlighting applications
- Exceptional color mixing
- Pre-set or dynamic RGB colors
- High resolution on dimming control
- Automatic white balance tracking on dimming
- Flexible connectivity interface
- User friendly control menu

1.3 System Overview

A block diagram of the system is shown in Figure 1-1.

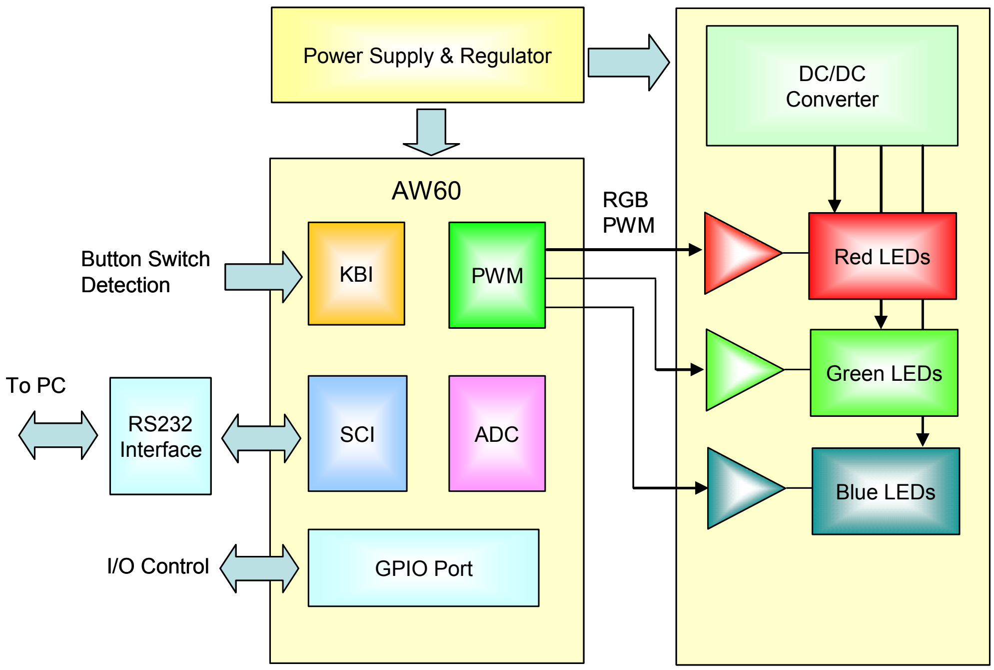


Figure 1-1 . System Block Diagram

1.4 MC9S08AW60

The MC9S08AW60, MC9S08AW48, MC9S08AW32, and MC9S08AW16 are members of the low-cost, high-performance HCS08 family of 8-bit microcontroller units (MCUs). All MCUs in the family use the enhanced HCS08 core and are available with a variety of modules, memory sizes, memory types, and package types. Refer to Table 1-1 for memory sizes and package types.

Table 1-2 summarizes the peripheral availability per package type for the devices available in the MC9S08AW60/48/32/16 series.

Table 1-1. Devices in the MC9S08AW60/48/32/16 Series

Device	Flash	RAM	Package
MC9S08AW60	63,280	2048	64 QFP 64 LQFP 48 QFN 44 LQFP
MC9S08AW48	49,152		
MC9S08AW32	32,768		
MC9S08AW16	16,384	1024	

Table 1-2. Peripherals Available per Package Type

	Package Options		
Feature	**64-Pin**	**48-Pin**	**44-Pin**
ADC	16-CH	8-CH	8-CH
IIC	Yes	Yes	Yes
IRQ	Yes	Yes	Yes
KBI1	8	7	6
SCI1	Yes	Yes	Yes
SCI2	Yes	Yes	Yes
SPI1	Yes	Yes	Yes
TPM1	6-CH	4-CH	4-CH
TPM1CLK	Yes	No	No
TPM2	2-CH	2-CH	2-CH
TPM2CLK	Yes	No	No
I/O Pins	54	38	34

Chapter 2
Hardware Description

2.1 Introduction

The system consists of a MCU control board and a LED driving board. The MCU control board, DEMO9S08AW60LED, is one of the demonstration boards for the Freescale MC9S08AW60. This board allows easier developmet of code for LED control applications, architectural/entertainment lighting or LCD backlighting. The on-board serial interface allows you to control and monitor the system status via the RS232 serial port connection. The separated LED light-box with driving circuitries is also available as a whole demo kit to demonstrate how to do the color mixing and see the visual effects on changing different type of parameter settings.

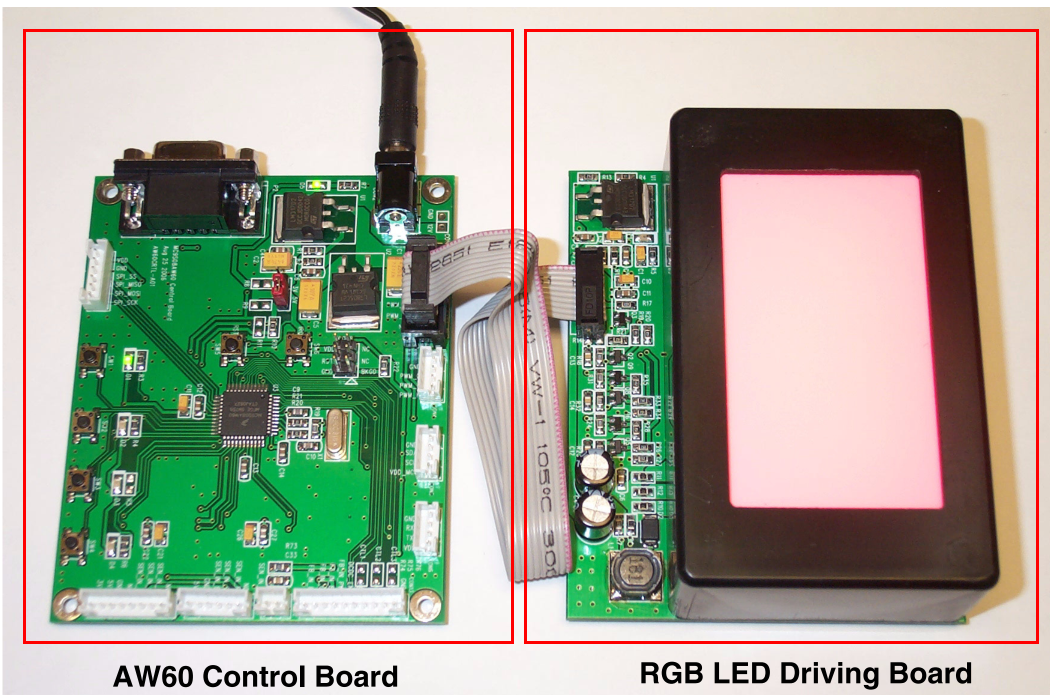


Figure 2-1. Light-Box Demo

2.2 DEMO9S08AW60LED Features

- MC9S08AW60 CPU
  - 44 pin LQFP package
  - 20 MHz Internal Bus Frequency
  - 60 Kbytes of on-chip in-circuit programmable FLASH
  - 2 Kbytes of on-chip RAM
  - 8-channel, 10-bit analog-to-digital converter
  - Two SCI modules
  - SPI module
  - I^2C module
  - 6-pin keyboard interrupt (KBI) module
  - 34 general-purpose input/output (I/O) pins
- External power jack for DC power supply (+12 VDC)
- Four pushbutton user switches
- Four LEDs connected to I/O port
- Master reset switch
- RGB PWM output port
- Optical sensor input port
- On-board RS-232 serial port
- 100mm x 80mm board size

2.3 DEMO9S08AW60LED Layout

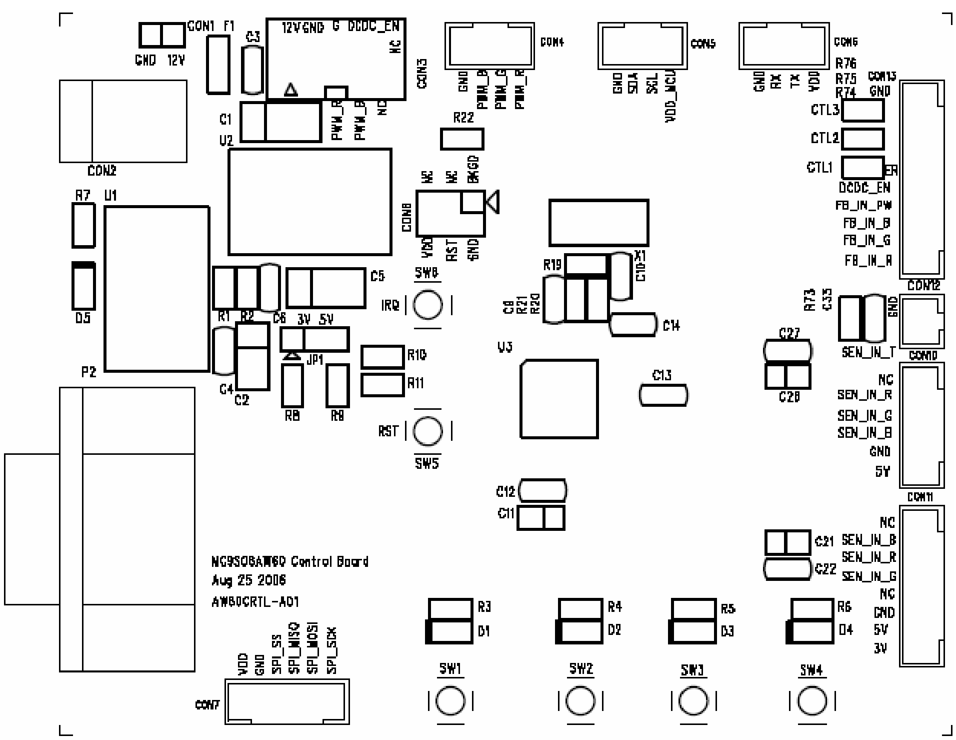


Figure 2-2. DEMO9S08AW60LED Top Side

2.4 Development Support

Application development and debug for the MC9S08AW60 is supported through a 6-pin BDM header (CON8). The pinout is as follows:

Table 2-1. BDM Connector (CON8) Pinout

BKGD	1	2	GND
NC	3	4	RESET
NC	5	6	V_{DD}

2.5 Power

The DEMO9S08AW60LED is powered externally through the barrel connector CON2. This connector is a 2.5 mm, center positive connector. Voltage supplied through this connector should be positive 12 volts DC. This is also the supply voltage for the LED light box.

The DEMO9S08AW60LED can be run with V_{DD} set to 5 or 3 volts. To run the board at 3V, move jumper JP1 to the 1-2, 3V position.

LED D5 turns green to let you know that power has been correctly applied to the board.

2.6 Reset Switch

The reset switch (SW5) provides a way to apply a reset to the MCU. The reset switch is connected directly to the $\overline{\text{RESET}}$ signal of the MCU. A 10 kΩ pullup resistor to V_{DD} on the RESET signal allows for normal operation. When the reset switch is pressed, the RESET signal is grounded and the MCU recognizes a reset.

2.7 Clock Source

An on-board 16 MHz crystal (X1) is connected between the XTAL and EXTAL pins of the MCU. This offers flexibility on clock source selection. Refer to the MC9S08AW60 data sheet for details on how to use the internal clock generation (ICG) module to generate the system clocks for the MCU.

2.8 RS-232

An RS-232 translator provides RS-232 communication on COM connector P2. This connector is a 9-pin Dsub right angle connector. TXD and RXD signals are routed from the MCU to the RS-232 transceiver.

Table 2-2 . RS-232 Connections

MCU Port	COM Signal	I/O Port Connector
PTE0/TXD1	TXD OUT	P2-2
PTE1/RXD1	RXD IN	P2-3

2.9 User Options

The DEMO9S08AW60LED includes various input and output devices to assist in application development. These devices include four pushbutton switches, four LEDs, and an operational amplifier with RC filter connected at each ADC input channel for signal amplification and filtering.

2.9.1 Pushbutton Switches

Four pushbutton switches provide momentary active low input for user applications. The table below describes the pushbutton switch connections.

Table 2-3. Pushbutton Switches (SW1-SW4) Connections

Switch	MCU Port
SW1	PTG0/KBI0
SW2	PTG1/KBI1
SW3	PTG2/KBI2
SW4	PTG3/KBI3

2.9.2 LED Indicators

Four green LED indicators (D1-D4) are provided to assist during code development. The LEDs are active low and illuminated when a logic low signal is driven from the MCU port pin. Two of the LEDs are connected to port A, and the other two are connected to Port C. The connections are described below:

Table 2-4. LEDs (D1-D4) Connections

LED	MCU Port
D1	PTA0
D2	PTA1
D3	PTC2
D4	PTC4

2.9.3 ADC Interface

Eight operational amplifiers are provided to assist users in developing applications with feedback control signals. For examples, the signal generated by an optical sensor in LED backlight system should be scaled to a level matched with the ADC input range without any saturation. Each operational amplifier can be configured as an inverting or non-inverting amplifier with variable gain setting by different resistor connections. A RC filter is also connected at each output for noise filtering.

NOTE

The maximum operational amplifier output voltage should be limited to the V_{DD} voltage applied to MCU to prevent any damage on input port.

2.9.4 Other I/O Connectors

One user assignable and eight pre-defined I/O connectors are available to help users connect the board into their target system.

Table 2-5. IIC Port

CON5	Signal Name	Remarks
Pin 1	NC	Install a zero ohm resistor in the R14 footprint to connect V_{DD}
Pin 2	SCL	Connected to MCU PTC0/SCL1 10 kΩ pullup to V_{DD}
Pin 3	SDA	Connected to MCU PTC1/SDA1 10 kΩ pullup to V_{DD}
Pin 4	GND	—

Table 2-6. SCI Port

CON6	Signal Name	Remarks
Pin 1	NC	Install a zero ohm resistor in the R15 footprint to connect V_{DD}
Pin 2	SCI_TX	Connected to MCU PTE0/TXD1
Pin 3	SCI_RX	Connected to MCU PTE1/RXD1
Pin 4	GND	—

Table 2-7. SPI Port

CON7	Signal Name	Remarks
Pin 1	NC	Install a zero ohm resistor in the R16 footprint to connect V_{DD}
Pin 2	GND	—
Pin 3	SPI_SS	Connected to MCU PTE4/$\overline{SS1}$
Pin 4	SPI_MISO	Connected to MCU PTE5/MISO1
Pin 5	SPI_MOSI	Connected to MCU PTE6/MOSI1
Pin 6	SPI_SCK	Connected to MCU PTE7/SPSCK1

Table 2-8. PWM Port

CON4	Signal Name	Remarks
Pin 1	PWM R	Connected to MCU PTF0/TPM1CH2
Pin 2	PWM G	Connected to MCU PTF1/TPM1CH3
Pin 3	PWM B	Connected to MCU PTE2/TPM1CH0
Pin 4	GND	—

Table 2-9. LED Light Box Interface

CON3	Signal Name	Remarks
Pin 1 & 2	12V	12V power for LED light box
Pin 3 & 4	GND	—
Pin 5	PWM R	Connected to MCU PTF0/TPM1CH2
Pin 6	PWM G	Connected to MCU PTF1/TPM1CH3
Pin 7	PWM B	Connected to MCU PTE2/TPM1CH0
Pin 8	DCDC_EN	Connected to MCU PTC3/TXD2 Reserved pin for DC to DC converter ON/OFF control
Pin 9 & 10	NC	—

Table 2-10. Sensor Interface Type A

CON10	Signal Name	Remarks
Pin 1	5V	Sensor supply voltage
Pin 2	GND	—
Pin 3	SEN_IN_B	Sensor input (Blue), Connected to MCU PTB2/ADP2 through operational amplifier U5B
Pin 4	SEN_IN_G	Sensor input (Green), Connected to MCU PTB1/ADP1 through operational amplifier U5A
Pin 5	SEN_IN_R	Sensor input (Red), Connected to MCU PTB0/ADP0 through operational amplifier U5D
Pin 6	NC	—

Table 2-11. Sensor Interface Type H

CON11	Signal Name	Remarks
Pin 1	3V	Sensor reference voltage
Pin 2	5V	Sensor supply voltage
Pin 3	GND	—
Pin 4	NC	—
Pin 5	SEN_IN_G	Sensor input (Green), Connected to MCU PTB1/ADP1 through operational amplifier U5A
Pin 6	SEN_IN_R	Sensor input (Red), Connected to MCU PTB0/ADP0 through operational amplifier U5D
Pin 7	SEN_IN_B	Sensor input (Blue), Connected to MCU PTB2/ADP2 through operational amplifier U5B
Pin 8	NC	—

NOTE

Connectors Type A and H share the same connection, so either one of the sensor interfaces can be used for sensor input.

Table 2-12. Temperature Sensor Input

CON12	Signal Name	Remarks
Pin 1	SEN_IN_T	10 kΩ pullup to V_{DD}, Connected to MCU PTB3/ADP3 through operational amplifier U5C
Pin 2	GND	—

Table 2-13. User Assignable Input

CON13	Signal Name	Remarks
Pin 1	FB_IN_R	Connected to MCU PTD0/ADP8 through operational amplifier U6D
Pin 2	FB_IN_G	Connected to MCU PTD1/ADP9 through operational amplifier U6A
Pin 3	FB_IN_B	Connected to MCU PTD2/ADP10 through operational amplifier U6B
Pin 4	FB_IN_PW	Connected to MCU PTD3/ADP11 through operational amplifier U6C
Pin 5	DCDC_EN	Connected to MCU PTC3/TXD2 and connector CON3 pin 8
Pin 6	DCDC_ER	Connected to MCU PTC5/RXD2

Table 2-13. User Assignable Input (Continued)

CON13	Signal Name	Remarks
Pin 7	DCDC_CTL1	Connected to MCU PTF4/TPM2CH0
Pin 8	DCDC_CTL2	Connected to MCU PTF5/TPM2CH1
Pin 9	DCDC_CTL3	Connected to MCU PTE3/TPM1CH1
Pin 10	GND	—

2.10 LED Driving Board

In general, LEDs have a nonlinear I-V behavior and current limitation is required to prevent the power dissipation to exceed a maximum limit. Therefore, the ideal source for LED driving is a constant current source. A linear type LED driver is used in this reference design and the block diagram is shown in Figure 2-4. The major advantage of linear driver is fast turn ON and OFF response times to support high frequency PWM dimming method and wide range control on dimming level. An integrated DC-to-DC boost converter (MC34063) generates the high voltage required for LED driving in series and is shared with RGB channels, but the drawback is the power loss on R channel is higher than G or B channels. Individual DC-to-DC block should be used for each channel in power sensitive applications.

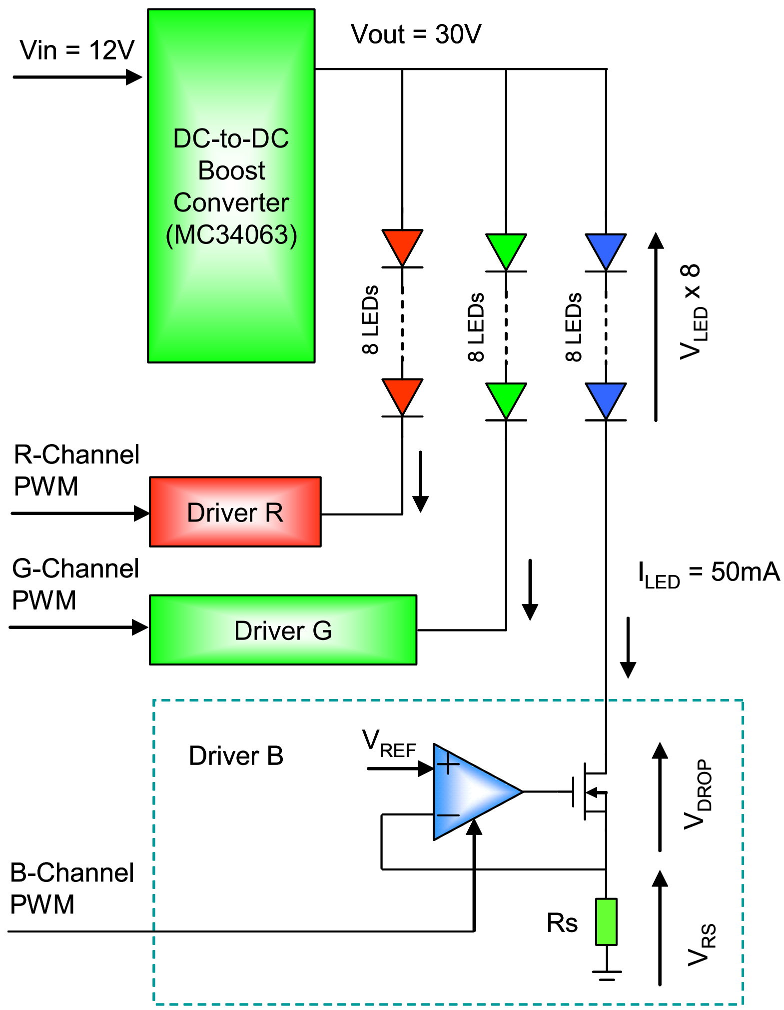


Figure 2-3. DC-to-DC Boost Converter and Linear LED Driver

Eight pieces of 3-in-1 RGB LED chips connected in series are used to form the multi-color light source. The LED chips are arranged in 2 x 4 format and each RGB LED string is driven by a separated constant current source. The average current through each RGB LED is controlled by an individual PWM signal generated from MCU. The final output color is determined by the mix of light emitted by RGB LEDs that are almost in linear relationship with PWM pulse width. An optical diffuser film should be placed on top of the display window for color mixing and brightness uniformity enhancement.

2.11 LED Driver Design Procedures

This section presents guidelines for selecting external components for DC-to-DC boost converter and linear drivers.

2.11.1 RGB LED Chip

The system is designed to drive eight pieces of RGB LED chips connected in a series. Assume the LED current for each color is 50mA and forward voltage is 2.3V for red LED and 3.3V for green and blue LEDs.

2.11.2 Current Sense Resistor

The value of the current sense resistor R_S is determined by two factors: power dissipation on R_S and the reference level V_{REF} for operational amplifier non-inverting input. Smaller R_S reduces power dissipation, but the detection of a feedback signal in operational amplifier is more difficult.

The voltage V_{RS} across the current sense resistor R_S is directly proportional to the current I_{LED} through LED. In closed-loop condition, V_{RS} is equal to the reference level V_{REF}, so the LED current I_{LED} is equal to the reference voltage V_{REF} divided by the current sense resistor R_S.

Setting V_{REF} to 1V and R_S equals 20Ω, the LED current I_{LED} is equal to 50mA.

Power dissipation on R_S is around 50mW, $I^2R = (50mA)^2 \times 20\Omega$, which is reasonable compared to total LED power.

2.11.3 Boost Converter

The switching regulator MC34063 from On Semiconductor is a monolithic circuit containing the primary functions required for DC-to-DC converters. It can be incorporated in boost converter application with minimum number of external components.

Boost Converter Calculations:

Output voltage $V_{OUT} > (V_{LED} \times 8) + V_{RS} + V_{DROP}$ (set maximum linear drop to 2 V)

Output current Iout > 50 mA x 3

Set V_{in} = 12 V, V_{out} = 30 V, and I_{out} = 175 mA

Refer to equations in Figure 2-4 to calculate the values for inductor and other external components.

Calculation	Step−Up
t_{on}/t_{off}	$\frac{V_{out} + V_F - V_{in(min)}}{V_{in(min)} - V_{sat}}$
$(t_{on} + t_{off})$	$\frac{1}{f}$
t_{off}	$\frac{t_{on} + t_{off}}{\frac{t_{on}}{t_{off}} + 1}$
t_{on}	$(t_{on} + t_{off}) - t_{off}$
C_T	$4.0 \times 10^{-5}\ t_{on}$
$I_{pk(switch)}$	$2I_{out(max)}\left(\frac{t_{on}}{t_{off}} + 1\right)$
R_{sc}	$0.3/I_{pk(switch)}$
$L_{(min)}$	$\left(\frac{(V_{in(min)} - V_{sat})}{I_{pk(switch)}}\right) t_{on(max)}$
C_O	$9\ \frac{I_{out}t_{on}}{V_{ripple(pp)}}$

Figure 2-4. Equations for Boost Converter

V_{sat} = Saturation voltage of the output switch.

V_F = Forward voltage drop of the output rectifier.

V_{in} - Nominal input voltage.

V_{out} - Desired output voltage.

I_{out} - Desired output current.

f_{min} - Minimum desired output switching frequency.

$V_{ripple(pp)}$ - Desired peak-to-peak output ripple voltage.

For further information, refer to On Semiconductor’s datasheet.

Chapter 3
Firmware Description

3.1 Introduction

The MCU firmware in this LED lighting control design is responsible for:

- Controlling timer channels for the RGB LED color PWM output
- Communicating with the host PC for receiving command and data input/output
- Operating as a standalone LED box through on board buttons

Figure 3-1 and Figure 3-2 shows the firmware flow. The LED box can operate in PC control operation mode or standalone operation mode.

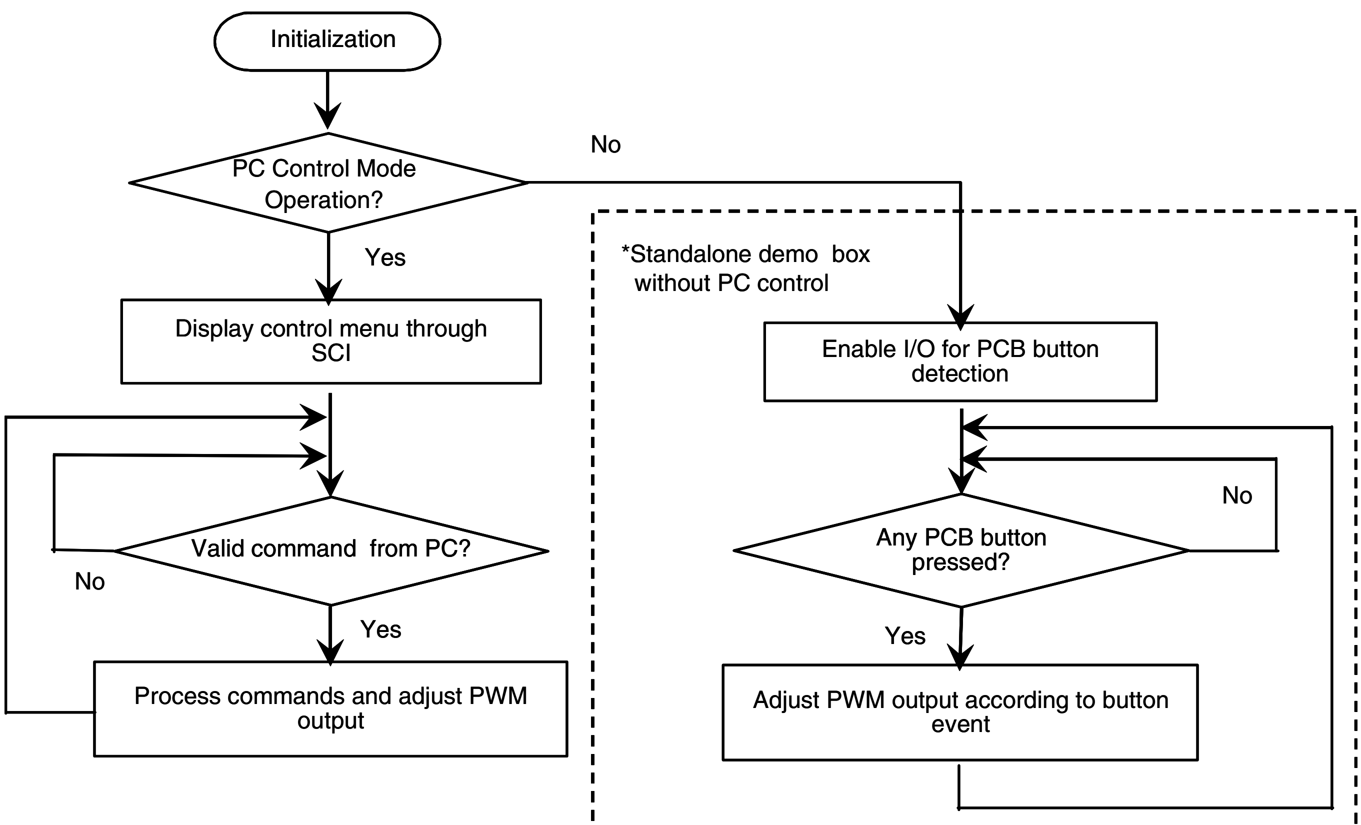


Figure 3-1. Firmware Flow: Main Program

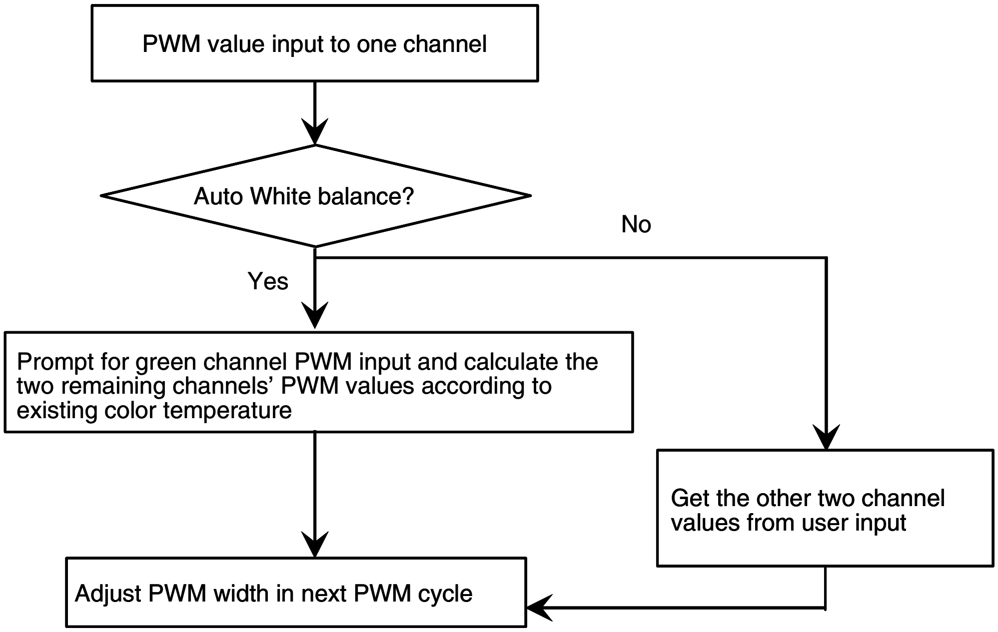


Figure 3-2. Firmware Flow: PWM Adjustment

3.2 PC Control Mode

Every time the MCU is powered up, the firmware detects the status of SW1. The LED lighting control box is operated in PC control mode if SW1 is not being pressed.

In this mode, you control the LED output through the host PC. The MCU uses the serial communication interface (SCI) module to communicate to the COM port of the host PC.

After entering this mode, the MCU sends out a number of string characters to the PC COM port. These strings are the contents of the user interface menu displayed in the PC screen. This user interface menu guides you on how to control the LED box by different function keys. The MCU also sends out existing PWM control parameters to the host for display. For examples, parameters such as existing RGB PWM output values, white balance mode, and PWM frequency are displayed. Figure 3-3 shows the PC screen for the user control menu.

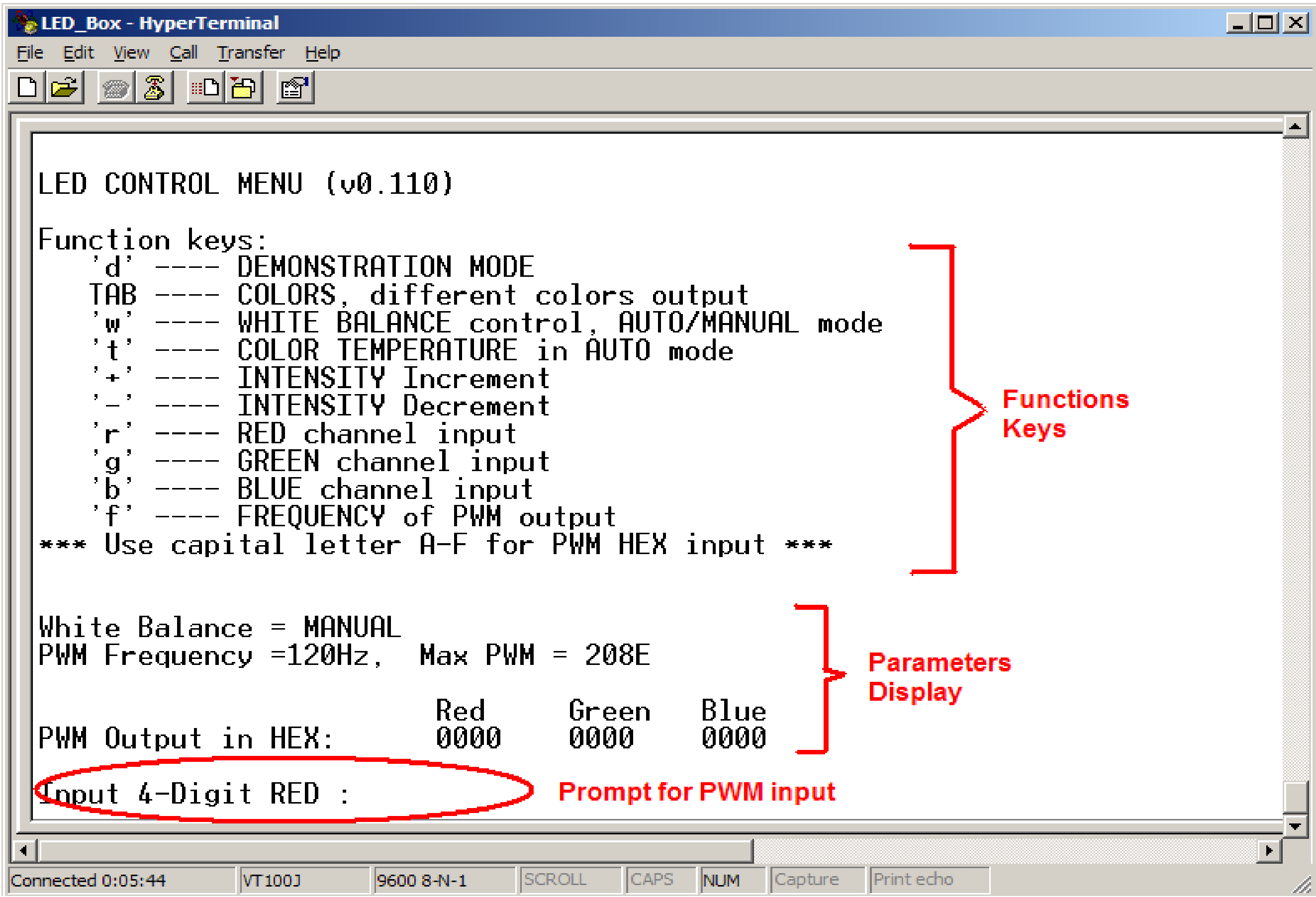


Figure 3-3. User Interface Menu

When the MCU receives a control command or PWM input data from the PC, the firmware interprets the information to take the corresponding actions. It may update the output PWM values in next PWM duty or delivery of the corresponding LED control parameter back to the PC. Three timer channels in the timer 1 module are configured to edge-aligned PWM operation mode. This generates the PWM signals for the RGB color channels.

By the proper control of the RGB channel PWM, the LED box can provide different lighting effects.

If you select the white balance mode to AUTO, the LED output gives a white color output. The firmware retains control of the RGB PWM ratio based on the preset white color. You can adjust the output brightness by pressing the + or – key in the host PC keyboard. Alternatively, you can input a green channel PWM value and the firmware calculates the blue and red PWM values to give the resultant intensity.

A demonstration display feature is available. After enabling this feature, the firmware adjusts RGB PWM so the light box switches among different preset colors, delivery fade in and fade out lighting effects, etc.

You can also set the PWM to different frequencies. At a lower PWM frequency, such as 30 Hz, the flicking phenomenon is more noticeable. This phenomenon can be minimized or removed by setting the PWM frequency to a higher value.

There are examples at the end of this section showing how to control the LED box through the host PC.

3.3 Standalone Mode

When the LED box is powered up with SW1 being pressed, it enters standalone mode. When compared to the PC control mode, this standalone mode can act as a quick and simple demo that does not require a host PC. The control of the LED light box can be done through the onboard buttons. However, the PC control mode can have more control on the PWM output.

The functions of the buttons are as follows:

- SW6 (IRQ): Demonstration Display Enable/Disable

  If SW6 is pressed, the LED box enters the demonstration display state where certain preset colors display sequentially with some other lighting effects. The demonstration mode can be exit by pressing SW6 again.
- SW1: Preset Colors Toggle

  Whenever SW1 has been pressed and released, the LED box toggles to another preset color. The LED1 lights up while LED2 turns off.
- SW2: Auto White Balance Control

  If SW2 has been pressed, the LED box turns to auto white balance state and give a white color. The small on board LED2 lights up while LED1 turns off, indicating an auto white balance state. There are two preset white color with different color temperatures available for selection. To swap between different preset color temperatures, press the SW2 button once more. The auto white balance state can be turn off by pressing SW1.
- SW3: Decrease Brightness

  The output brightness increases if SW3 has been pressed.
- SW4: Increase Brightness

  The output brightness decreases if SW4 has been pressed.
- SW1+SW2: PWM Frequency Selection

  The Output PWM Frequency can be changed with following steps:

  1. Press and hold SW1
  2. Press SW2
  3. Release SW2
  4. Release SW1

  After performing the above action, the output PWM frequency can be changed. There are three preset settings available, 30 Hz, 120 Hz, and 600 Hz. For examples, after changing from 30 Hz to 120 Hz using above steps, it can set the PWM to 600 Hz by applying the above steps again.

NOTE

The output brightness is changed after changing the frequency. As the PWM output values remain the same, a change in PWM frequency modifies the PWM duty as well.

The PWM frequency selection steps above are invalid if the LED box is running at demonstration display state. In addition, the PWM frequency is changed to the default value of 120 Hz after the demonstration display state has been exited by pressing SW6.

3.4 Firmware Files

Below is a list of the C files in the firmware

Main.c

- Programs entry point and determination of operation mode, i.e. PC control mode or standalone operation mode
- System initialization
- Common functions used in different firmware modules

Menu.c

- Takes care of high level user interface communication with the PC host.
- Interprets the received PC commands or data and initiate the corresponding action. The user interface menu contents can be modified or edited in this file.

SCI.c

- Takes care of low level SCI hardware for communication between the PC. Functions that accessing the SCI registers are included in this file.
- String management for input and output functions used in the Menu.c

ISR.c

- Interrupt services routines for different hardware modules
- Timer 1 is used for the PWM channels for the three RGB output color
- Timer 2 is used for generating a periodical interrupt that used in the demonstration display feature
- IRQ interrupts for enabling or disabling of demonstration display in the standalone operation mode.
- KBI interrupts for on board buttons detection
- Functions for generating certain display effects are included in this file

Keyinput.c

- For operation of standalone mode without the host PC

Chapter 4
Demo Setup

4.1 Introduction

This section shows how to connect the DEMO9S08AW60LED board to your PC, run the demo program, and how to program the board with the source code. The source code can be download from the Freescale website.

4.2 Hardware and Software Setup

The DEMO9S08AW60LED is shipped with the demo program stored in on-chip flash memory. Use Figure 2-2 as a guide to do the setup.

4.2.1 Hardware Setup

1. Check the jumper setting and make sure jumper JP1 on DEMO9S08AW60LED board is set to the 5V (2-3) position.
2. Connect the 2x5 pin ribbon flat cable at LED light box to connector CON3 on DEMO9S08AW60LED board.
3. Connect a serial cable to the PC or notebook and then to the DEMO9S08AW60LED board.
4. Power up the demo through the DC jack connector CON1 on DEMO9S08AW60LED board. The supply voltage is 12V DC and LED D5 should be on.
5. Press SW5 to reset the MCU. The LED light box demo enters PC control mode. (Make sure SW1 is not pressed during reset.)

4.2.2 PC Software Setup

1. Open up a terminal window from within Windows XP by clicking on Start → All Programs → Accessories → Communications → HyperTerminal
2. Give your terminal connection a name (such as AW60_Control) and click the OK button.
3. In the Connect using pulldown, select the COM port you connected your serial cable to, and click the OK button.
4. In the Port Settings window, click the OK button after entering the following settings:

   Bits per second: 9600

   Data bits: 8

   Parity: None

   Stop bits: 1

   Flow control: None
5. Make sure Echo typed characters locally is NOT selected under the ASCII Setup pop-up menu, see Figure 4-1.
6. After configuring HyperTerminal, the LED Control Menu screen appears as shown in Figure 4-2.

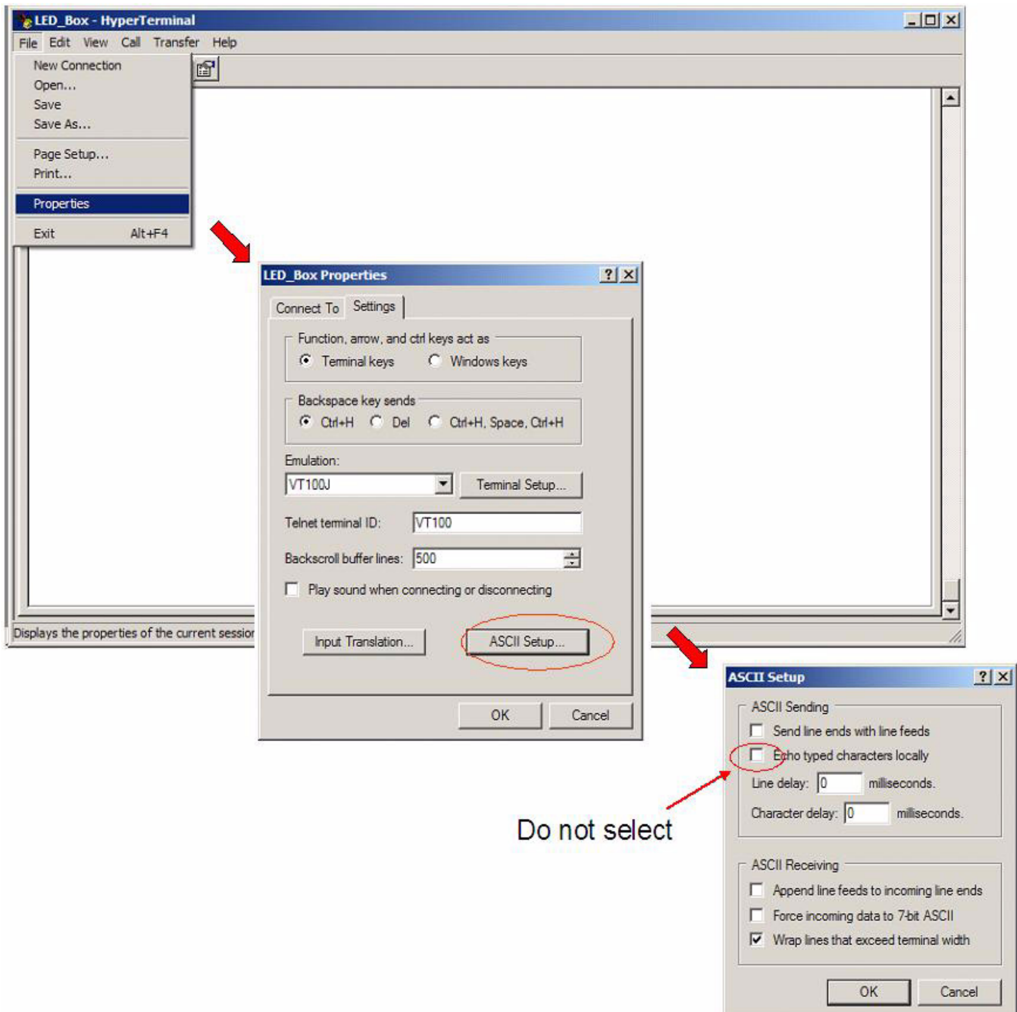


Figure 4-1. Echo Typed Characters Setting

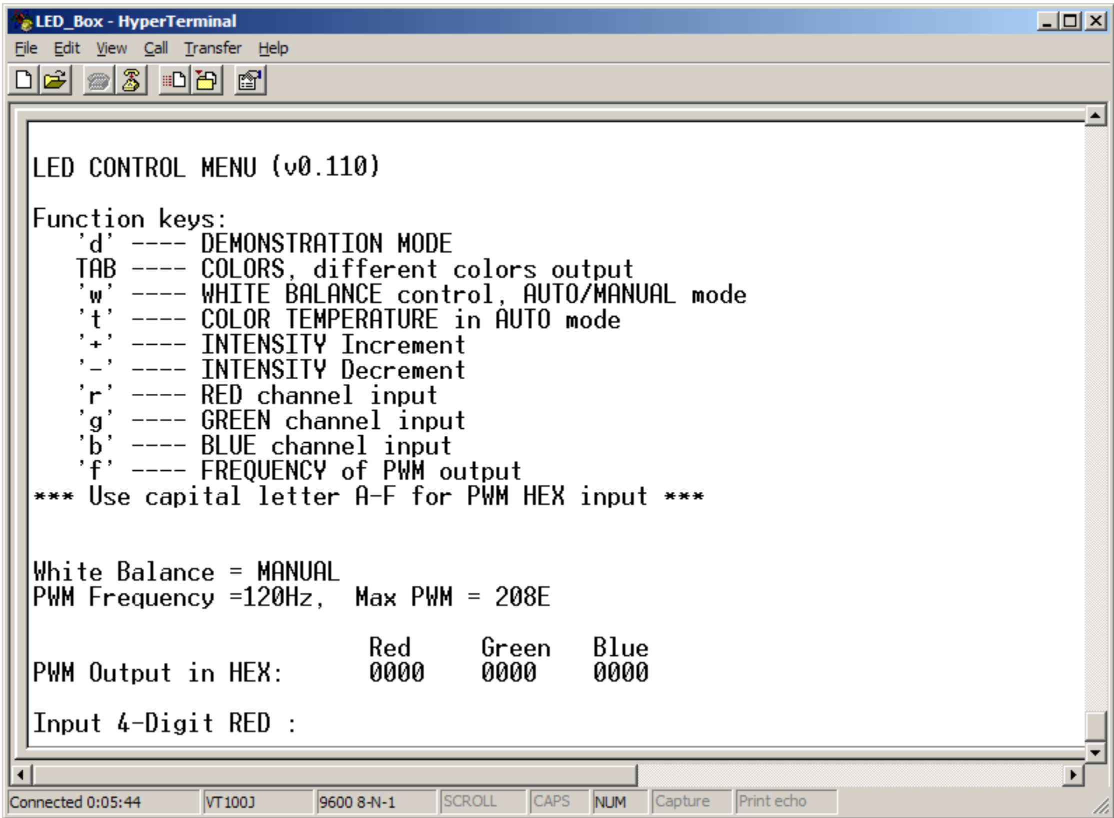


Figure 4-2. LED Control Menu

NOTE

Make sure the HyperTerminal window is selected all the time by moving the mouse pointer inside the window and clicking the left mouse button (the top color bar of the terminal window is then blue instead of grey). Otherwise, no function key command is sent to the LED lightbox.

4.3 Demo Examples

Several examples are given here on showing how to use the LED box under the PC control.

4.3.1 Demo 1 - Demonstration Display

1. Press the reset button SW5 on DEMO9S08AW60LED board. The LED control menu screen appears (Figure 4-2).
2. Press letter D in the PC keyboard to enter demonstration display operation.
3. In this display state, the LED light box switches among different colors automatically and delivers other lighting effects.

NOTE

Press any other key to exit demonstration display. Press D to enter demonstration display again.

4.3.2 Demo 2 - Preset Colors Display

1. Press the tab key in the PC keyboard.
2. The output is switched to another preset color after the tab key has been pressed each time.

NOTE

You can adjust the output color any time through the control menu.

4.3.3 Demo 3 - Auto White Balance Control

1. Press F until PWM frequency is set to 120 Hz.
2. Press W to toggle to AUTO white balance control.
3. Type 2000 at line of input green. The green PWM output value should then show 2000.
4. The red and blue PWM values are adjusted automatically to keep the output at the existing color temperature.

Note:

Pressing T can change the output to another preset color temperature.

Pressing the + or – key can gradually increase or decrease the output intensity. Use the + or – keys from the main keyboard area instead of those near the NUM lock key pad.

Max PWM input range is decreased if setting to a higher PWM frequency.

4.3.4 Demo 4 - PWM Output Frequency Control

1. Press W to toggle the output to AUTO mode.
2. Pressing F can switch the PWM output among different preset frequencies.
3. The flicking phenomenon is more significant at the lower frequency such as at 30 Hz. The flicking can be removed by setting PWM to higher frequencies.

NOTE

The output brightness is changed after changing the frequency. As the PWM output values remain the same, a change in PWM frequency modifies the PWM duty as well.

As the frequency increases, the max allowable PWM input range decreases because the PWM value for 100% on-duty becomes smaller.

4.3.5 Demo 5 - Full Manual Control

1. Press F until PWM frequency change to 120Hz
2. Press W to toggle the output to MANUAL mode.
3. Press R to switch to manual red channel input.
4. Type 2000 at the Input red line.
5. Press G to switch to manual green channel input.
6. Type 0000 at the Input green line.
7. Press B to switch to manual blue channel input.
8. Type 2000 at the input blue line.
9. The output color is purple. You can repeat the steps with different PWM values for different output colors and intensities.

NOTE

Max PWM input range is decreased when setting to a higher PWM frequency. With the same PWM values, increasing frequency (i.e. shorter period) increases brightness because the PWM on-duty increases.

When typing HEX PWM input values, use only capital letters for the input of A–F.

4.4 Program the MCU Flash

The DEMO9S08AW60LED board allows you to program the MCU flash and debug applications via the BDM connection.

1. Download the source code file from Freescale web site, save it to your PC, and extract the files to a working directory on your machine.
2. Open CodeWarrior HC(S)08 v5.1 and open the LED_box.mcp project file.
3. Open main.c in the sources folder by clicking the plus sign next to the sources folder and then double clicking on main.c. This is the application code.
4. Connect the BDM cable from your development tools to the DEMO9S08AW60LED board (CON8).
5. Connect a serial cable to the PC and then to the DEMO9S08AW60LED board.
6. Power up the demo through the DC jack connector CON1 on DEMO9S08AW60LED board.
7. Open up a terminal window from within Windows XP by clicking on Start → All Programs → Accessories → Communications → HyperTerminal
8. Give your terminal connection a name (such as AW60_Control) and click the OK button.
9. In the Connect using pulldown, select the COM port you connected your serial cable to, and click the OK button.
10. In the Port Settings window, click the OK button after entering the following settings:

    Bits per second: 9600

    Data bits: 8

    Parity: None

    Stop bits: 1

    Flow control: None.
11. In the Freescale CodeWarrior window, click on Debug under Project in the menu bar or press F5. The True-Time Simulator and Real-Time Debugger interface window appears.
12. When the ICD Connection Assistant appears, click the Connect button.
13. When the Erase and Program Flash window appears, click the yes button.
14. The CPROGHCS08 Programmer window should close after the MCU flash is programmed. To run the source code, click on Start/Continue under Run in the menu bar or click the green arrow.

4.5 Troubleshooting

1. V_{DD} LED does not turn on

    Make sure jumper JP1 is set to the 5V (2-3) position.
2. The light box does not display any color

    Make sure the 2x5 pin ribbon flat cable at LED light box is installed properly to the DEMO9S08AW60LED board.

Repeat the PC software setup procedures again.

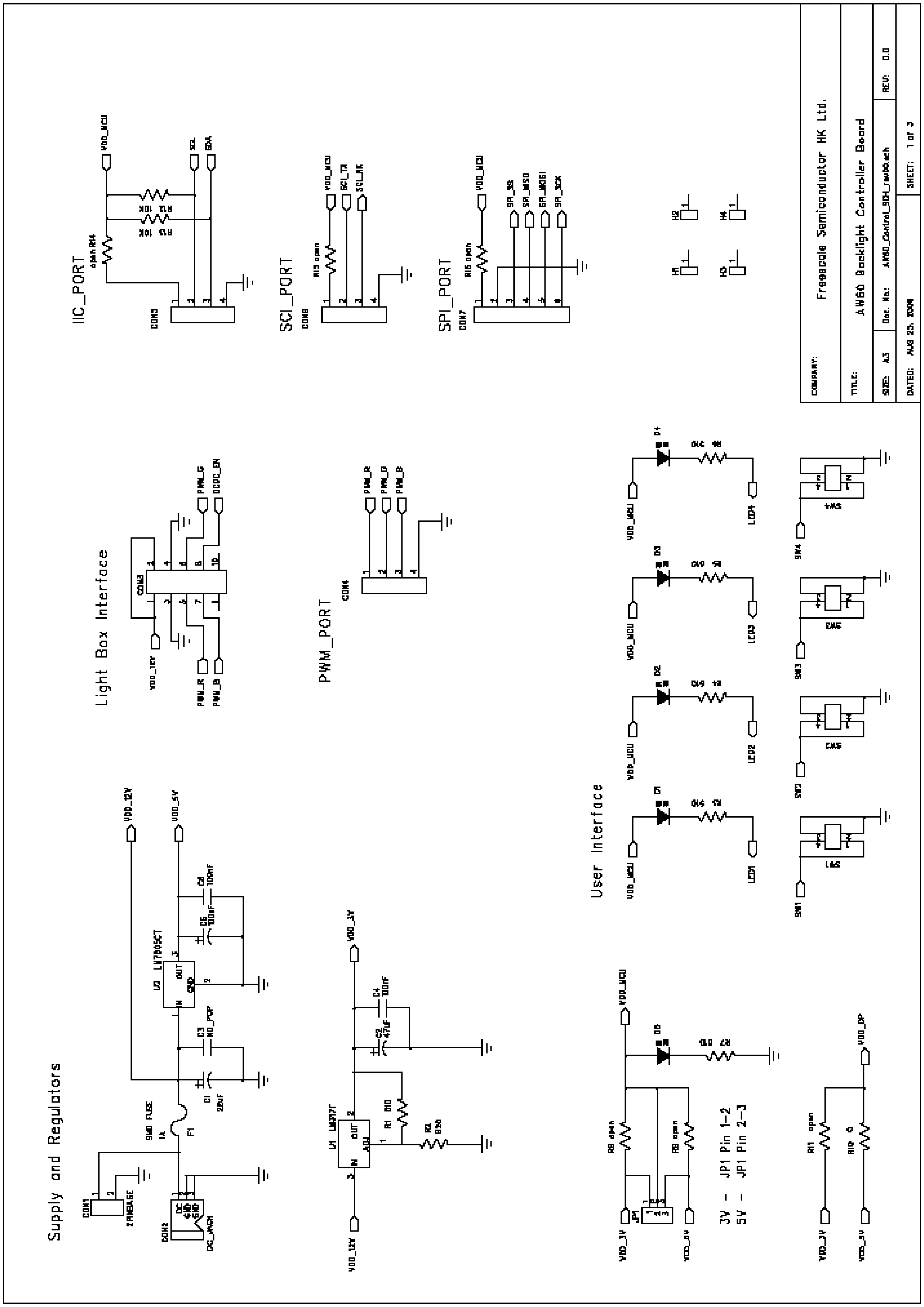
3. Control menu contents are not correct

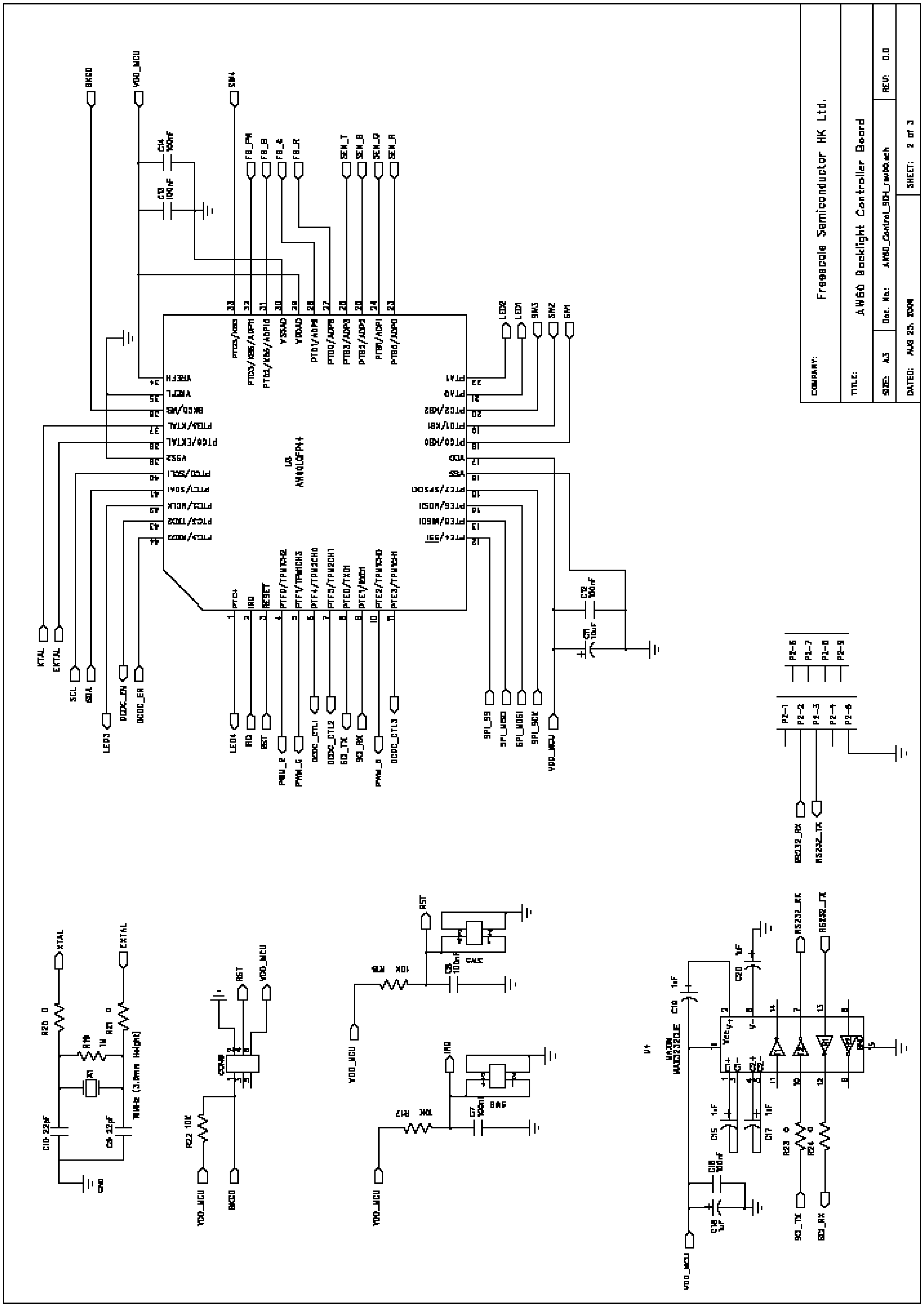
   Make sure the COM port selection is correct.
   Check the Port Settings again and make sure the configurations are correct.

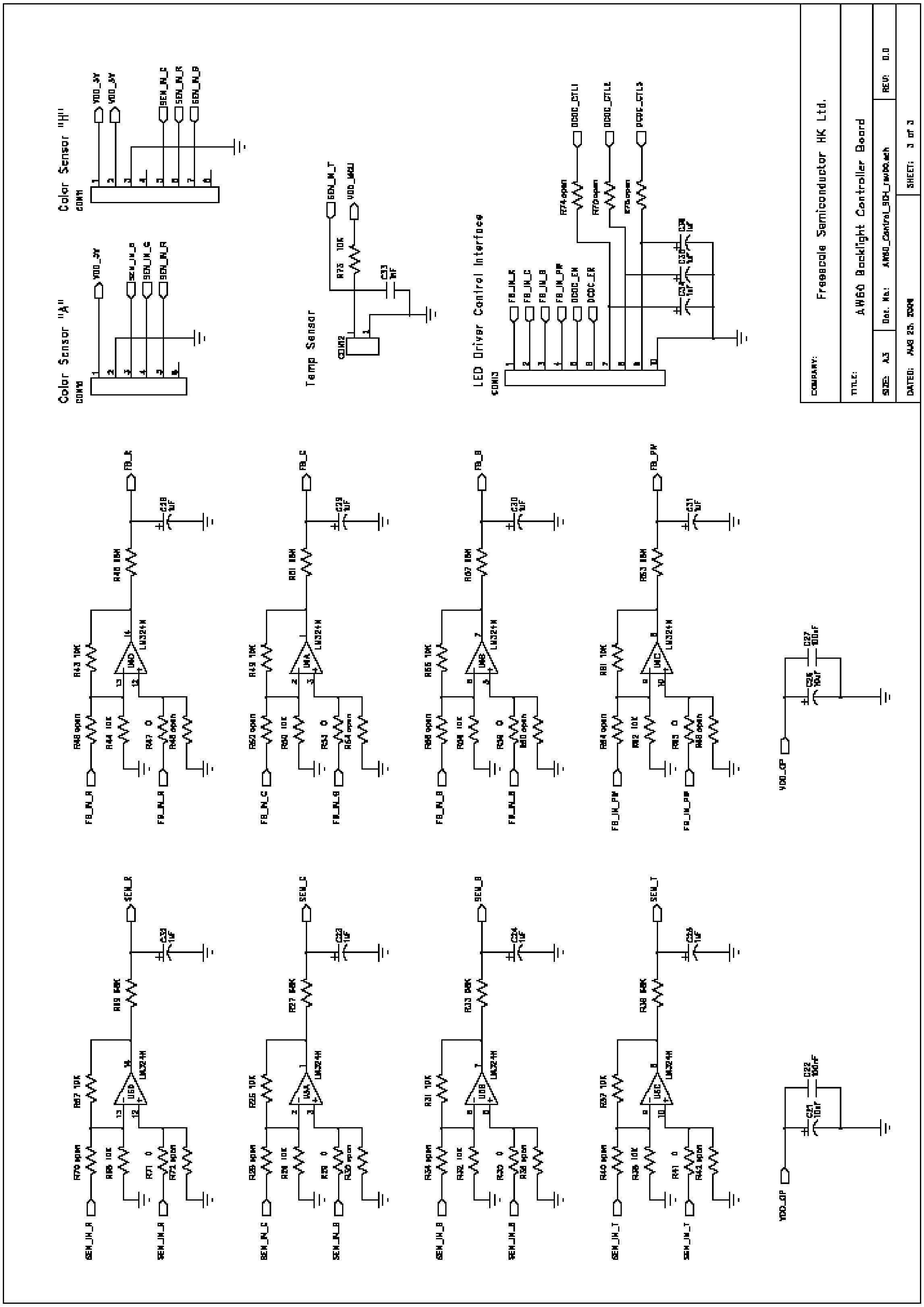
4. User input does not be detected correctly

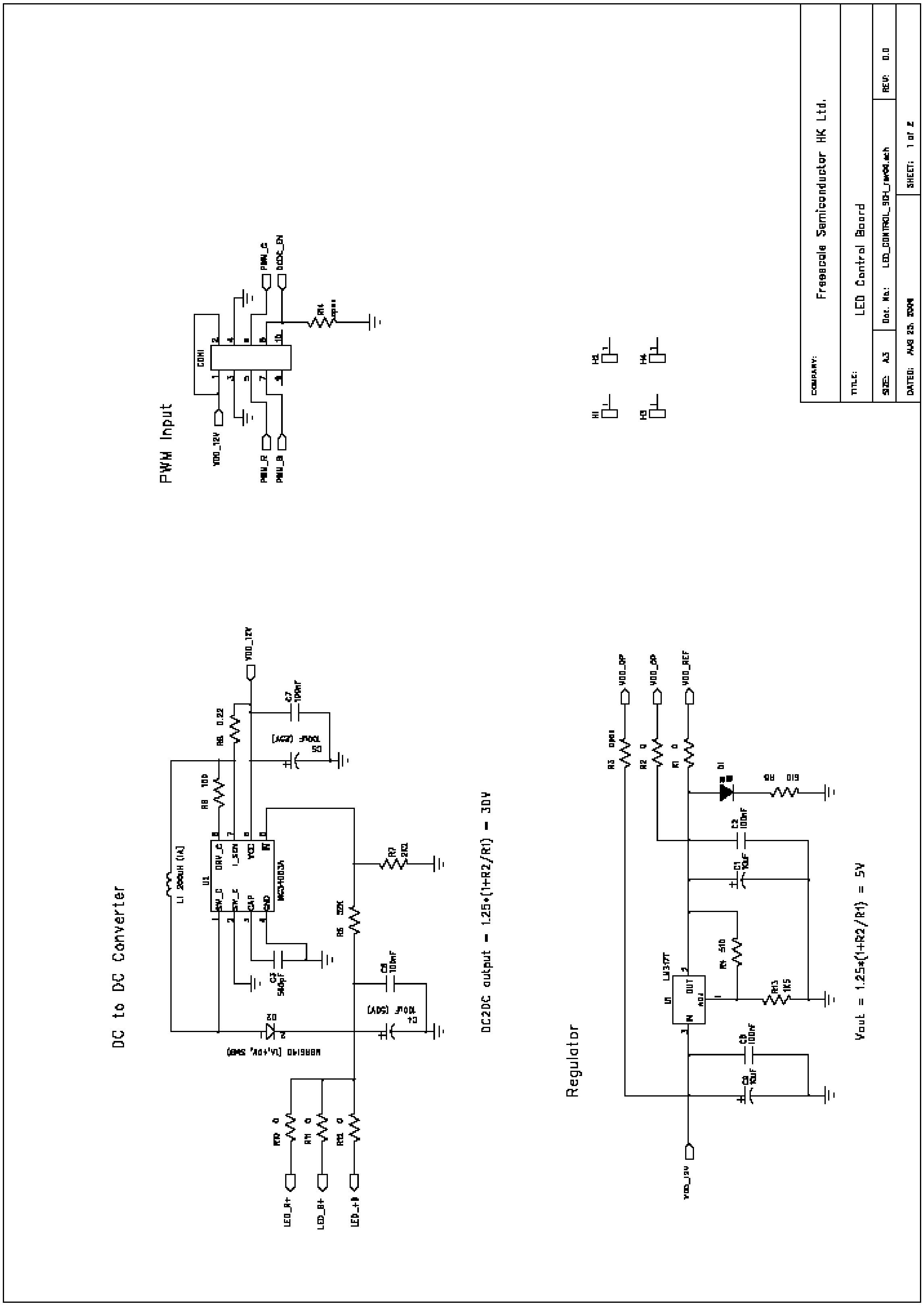
   Make sure the HyperTerminal Window is being selected all the time.
   When typing HEX PWM input values, use ONLY CAPITAL letter for the input of A–F.
   Use the + or – keys from the main keyboard area instead of those near the NUM lock key pad.

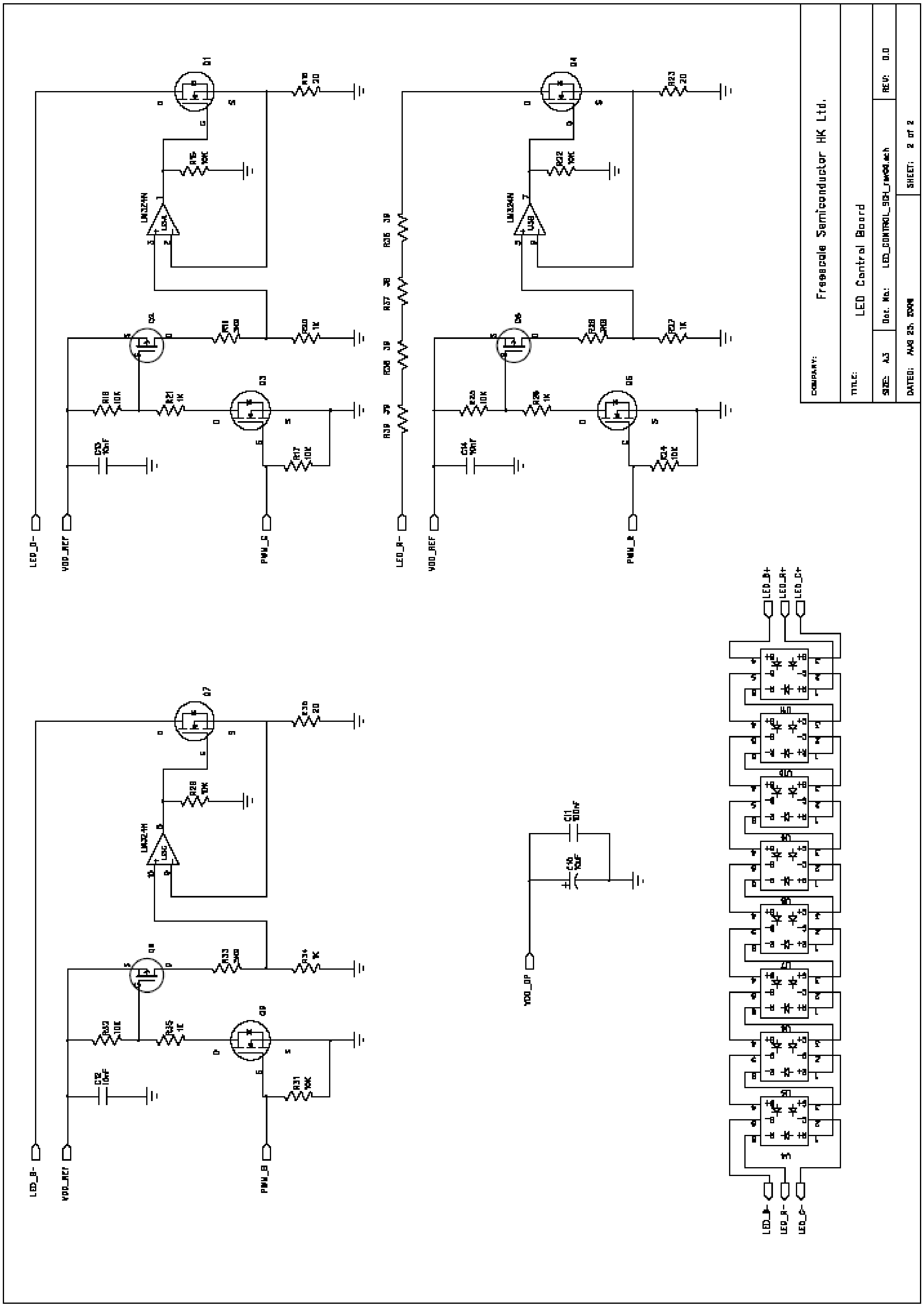
Appendix A
Schematics


Supply and Regulators
Light Box Interface
IIC_PORT
SCI_PORT
SPI_PORT
PWM_PORT
User Interface
3V - JP1 Pin 1-2
5V - JP1 Pin 2-3
Freescale Semiconductor HK Ltd.
AW60 Backlight Controller Board


Freescale Semiconductor HK Ltd.
AW60 Backlight Controller Board


Color Sensor "A"
Color Sensor "H"
Temp Sensor
LED Driver Control Interface
Freescale Semiconductor HK Ltd.
AW60 Backlight Controller Board


DC to DC Converter
DC2DC output = 1.25*(1+R2/R1) = 30V
PWM Input
Regulator
Vout = 1.25*(1+R2/R1) = 5V
Freescale Semiconductor HK Ltd.
LED Control Board


Freescale Semiconductor HK Ltd.
LED Control Board

Appendix B
Bill of Materials

Table 4-1 BOM for AW60 Control Board

Part Description	Quantity	Value	Designators
SMD RESISTOR	6	510	R1 R3-7
SMD RESISTOR	1	820	R2
SMD RESISTOR	25	open	R8 R9 R11 R14-16 R28 R30 R34 R36 R40 R42 R46 R48 R52 R54 R58 R60 R64 R66 R70 R72 R74-76
SMD RESISTOR	22	10K	R32 R12 R37-38 R17-18 R43-44 R49-50 R22 R55-56 R61-62 R25-26 R67-68 R13 R73 R31
SMD RESISTOR	13	0	R35 R23 R59 R24 R47 R65 R20 R41 R71 R21 R29 R10 R53
SMD RESISTOR	1	1M	R19
SMD RESISTOR	8	68K	R69 R27 R63 R51 R57 R39 R45 R33
SMD CER CAPACITOR	10	100nF	C4 C6-8 C12-14 C16 C22 C27
SMD CER CAPACITOR	1	NO_POP	C3
SMD CER CAPACITOR	2	22pF	C9-10
SMD CER CAPACITOR	1	1nF	C33
SMD TAN CAP	16	1uF	C18-20 C15 C23-25 C17 C28-32 C34-36
SMD TAN CAP	3	10uF	C11 C21 C26
SMD TAN CAP	1	47uF	C2
ECAP	1	100uF (25V)	C5
ECAP	1	22uF (50V)	C1
2.54mm HEADER	1	2x3 Pin (2.54mm Pitch)	CON8
2.54mm HEADER	1	2x5 Pin (2.54mm Pitch with polarity)	CON3
2.5mm CONNECTOR BASE	1	1x2 Pin (2.5mm Pitch) NO_POP	CON1
JUMPER	1	3 PIN (2.5mm Pitch) Short 2-3	JP1
2mm CONNECTOR BASE	1	1x2 Pin (2mm Pitch with polarity)	CON12
2mm CONNECTOR BASE	3	1x4 Pin (2mm Pitch with polarity)	CON4-6
2mm CONNECTOR BASE	1	1x6 Pin (2mm Pitch with polarity)	CON7
2mm CONNECTOR BASE	1	1x6 Pin (2mm Pitch with polarity)	CON10
2mm CONNECTOR BASE	1	1x8 Pin (2mm Pitch with polarity)	CON11
2mm CONNECTOR BASE	1	1x10 Pin (2mm Pitch with polarity)	CON13
DB9 HORIZ FEMALE PCB CONNECTOR	1	DB9 HORIZ FEMALE PCB CONNECTOR	P2
DC JACK CONNECTOR	1	12V DC JACK	CON2
SMD TACT SW	6	5mm x 5mm	SW1-6
Plastic POST	4	3-4mm Height	H1-4
Crystal	1	16MHz (3.5mm Height)	X1
LED	5	SMD GREEN	D1-5
FUSE	1	SMD FUSE 1A	F1
QUAD OP AMP	2	LM324 (SO14 Package)	U5-6
SERIAL PORT DRIVER/RECEIVER	1	MAX3232CUE TSSOP16	U4
ADJUSTABLE VOLTAGE REGULATOR	1	LM317 (D2PAK)	U1
5 VOLT REGULATOR	1	LM7805 (D2PAK)	U2
MCU	1	MC9S08AW60CFGE (LQFP44)	U3

Table 4-2 BOM for LED Driving Board

Part Description	Quantity	Value	Designators
SMD RESISTOR	5	0	R1-2 R10-12
SMD RESISTOR	1	52K	R6
SMD RESISTOR	1	2K2	R7
SMD RESISTOR	1	0.22	R8
SMD RESISTOR	1	180	R9
SMD RESISTOR	2	open	R3 R14
SMD RESISTOR	1	510	R5
SMD RESISTOR	1	1K5	R13
SMD RESISTOR	1	510	R4
SMD RESISTOR	9	10K	R15 R17-18 R22 R24-25 R29 R31-32
SMD RESISTOR	3	3K9	R19 R26 R33
SMD RESISTOR	6	1K	R27-28 R21 R20 R34-35
SMD RESISTOR	3	20	R30 R16 R23
SMD RESISTOR	4	39	R36-R39
SMD CER CAPACITOR	4	100nF	C2 C7-8 C11
SMD CER CAPACITOR	1	560pF	C3
SMD CER CAPACITOR	3	10nF	C12-14
High Volt SMD CER CAPACITOR	1	100nF (50V)	C6
SMD TAN CAP	3	10uF	C1 C9-10
ECAP	2	100uF (50V)	C4-5
INDUCTOR Coil	1	SMD 200uH (1A)	L1
LED	1	SMD GREEN	D1
N-CHANNEL MOSFET	3	ZVN2106G (8A, 60V, SOT223)	Q1 Q4 Q7
N-CHANNEL MOSFET	3	MMBF0201NL (300mA, 20V, SOT-23)	Q6 Q3 Q9
P-CHANNEL MOSFET	3	NTR0202PL (400mA, 20V, SOT-23)	Q2 Q5 Q8
SMD SCHOTTKY DIODE	1	MBRS140 (1A,40V, SMB)	D2
QUAD OP AMP	1	LM324M (SO14 Package)	U3
ADJUSTABLE VOLTAGE REGULATOR	1	LM317M (D2PAK)	U1
DC-TO-DC CONVERTER	1	MC34063A SO8	U2
OSRAM LED	8	RGB LED (6-Pin SMD)	U4-11
Plastic Box	1	100mm x 60mm (Black Color)	with a 70mmx 40mm display window and mount on the PCB Board
SCREW	4	Use Plastic Box 's screw	H1-4
PLASTIC POST	4	3-4mm Height (Paste on bottom side)	
3M Diffuser Film	2	100mm x 60mm (Ref number: 3635-70)	Paste 2 sheets under the plastic box cover
FLAT RIBBON CABLE	1	2x5 pin flat ribbon cable, 20cm length (2.54mm pitch, one end soldering type)	CON1

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